Solution of Experimental Problem.

A transformer is built-in in a “black box”. The black box has 4 terminals. To be able to determine the equivalent circuit and the parameters of its elements one may first carry out measurements of the direct current. The most expedient is to mount the circuit according to the layout in Fig.3 and to build volt-ampere characteristics for various terminals of the “box”. This enables one to make sure rightway that there were no e.m.f. sources in the “box” (the plot $I=f(U)$ goes through the origin of the coordinates), no diodes (the current strength does not depend on the polarity of the current’s external source), by the inclination angle of the plot one may define the resistances between different terminals of the “box”. The tests allowed for some estimations of values $R_{1\text{-}2}$ and $R_{3\text{-}4}$. The ammeter did not register any current between the other terminals. This means that between these terminals there might be some other resistors with resistances larger than R_L :

$$R_L = \frac{U_{\max}}{I_{\min}} = \frac{4{,}5\,\text{V}}{2\cdot 10^{-6}\,\text{A}} = 2.25\cdot 10^{6}\,\text{ohm}$$

where $I_{\min}$ - the minimum value of the strength of the current which the instrument would have registered. Probably there might be some capacitors between terminals 1-3, 1-4, 2-3, 2-4 (Fig.4).

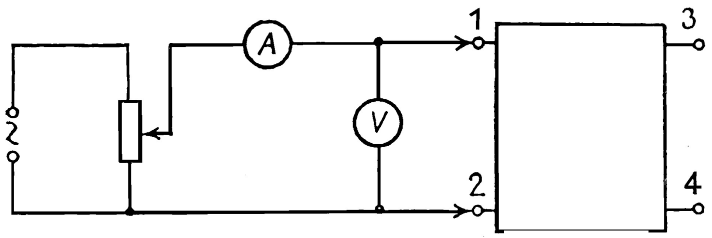
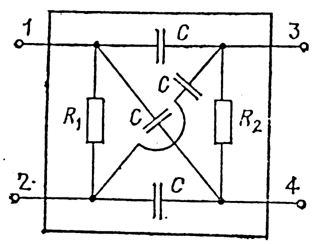


Fig.3

Then, one can carry out analogous measurements of an alternative current. The taken volt-ampere characteristics enabled one to find full resistances on the alternative current of sections 1-2 and 3-4: Z_1 and Z_2 and to compare them to the values R_1 and R_2. It turned out, that $Z_1 > R_2$ and $Z_2 > R_2$.



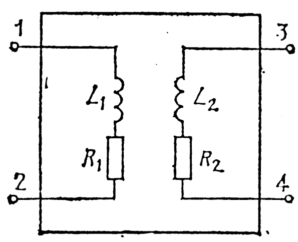


Fig.4 Fig.5

This fact allows one to conclude that in the "black box" the coils are connected to terminals 1-2 and 3-4 (Fig.5). Inductances of coils L_1 and L_2 can be determined by the formulas

$$L_1 = \frac{\sqrt{Z_1^2 - R_1^2}}{2\pi\nu}, \qquad L_2 = \frac{\sqrt{Z_2^2 - R_2^2}}{2\pi\nu}.$$

After that the dependences $Z = f(I)$, $L=f(I)$ are to be investigated. The character of the found dependences enabled one to draw a conclusion about the presence of ferromagnetic cores in the coils. Judging by the results of the measurements on the alternative current one could identify the upper limit of capacitance of the capacitors which could be placed between terminals 1-3, 1-4, 2-3, 2-4:

$$C_{\max} = \frac{I_{\min}}{2\pi\nu U_{\max}} = \frac{5\cdot 10^{-6}\,\mathrm{A}}{2\cdot 3.14\cdot 50\mathrm{s}^{-1}\cdot 3\mathrm{V}} = 5\cdot 10^{-9}\,\mathrm{F} = 5\mathrm{nF}$$

Then one could check the availability of inductive coupling between circuits 1-2 and 3-4. The plot of dependence of voltage $U_{3\text{-}4}$ versus voltage $U_{1\text{-}2}$ (Fig. 6) allows one to find both the transformation coefficient

$$K = \frac{U_{1-2}}{U_{3-4}} = \frac{1}{2}$$

and the maximum operational voltages on coils L_1 and L_2, when the transformation

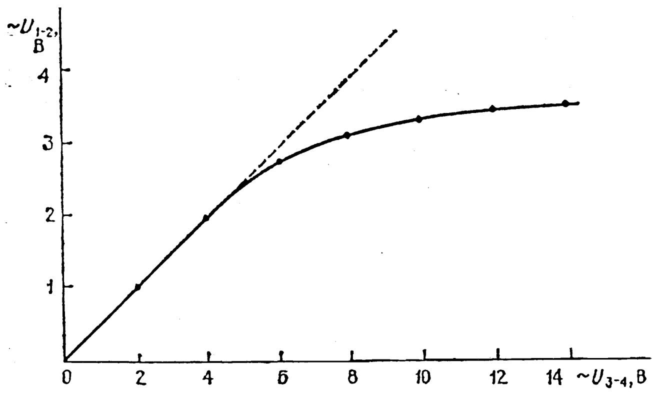


Fig.6

coefficient has not changed yet, i.e. before saturation of the core.

$U_{1\text{-}2(\max)}$=2.5 V, $U_{3\text{-}4(\max)}$ = 5 V.

One could build either plot $K(U_{1\text{-}2})$ or $K(U_{3\text{-}4})$ (Fig. 7).

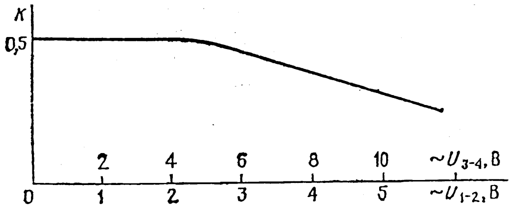


Fig.7

Note: It was also possible to define the "box" circuit after tests of the direct current. To do that one had to find the presence of induction coupling between terminals 1-2 and 3-4, that is the appearance of e.m.f. of induction in circuit 3-4, when closing and breaking circuits 1-2 and vice-versa. When comparing the direction of the pointer's rejection of the voltmeters connected to terminals 1-2 and 3-4 one could identify directions of the transformer's windings.

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